Exploration Systems Development Update

NASA Advisory Council
July 25, 2016

Bill Hill, Deputy Associate Administrator
Exploration Systems Development

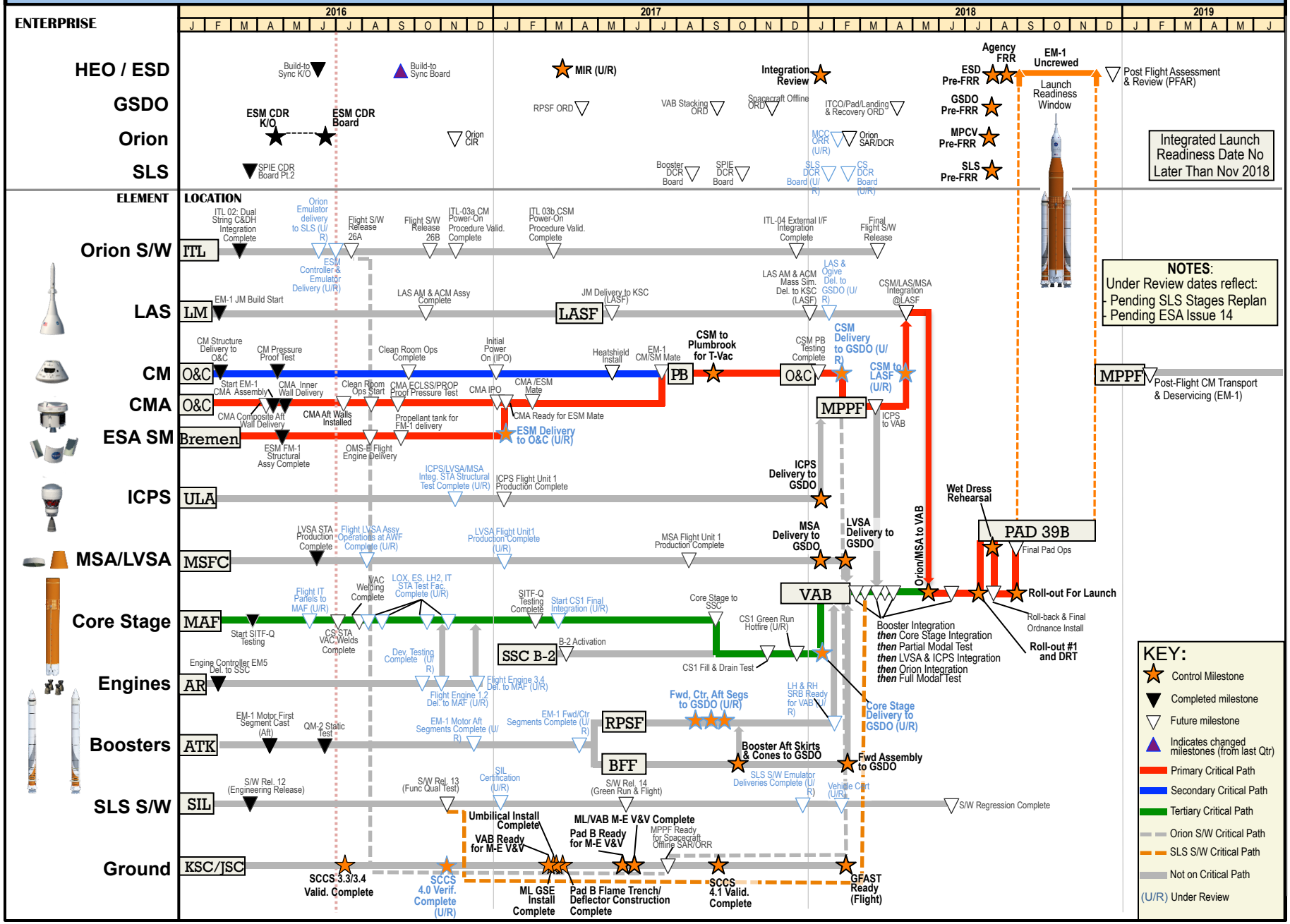
ESD HQ Milestones - January 2016-June 2016

January 2016		
Orion	EM-1 Ogive Production Start	**Complete.**
SLS	Start VAC Weld Confidence Article	**Complete.**
February 2016		
Orion	ESM STA Ready for Test	**Complete.**
SLS	Engine Controller EM-5 Delivery to SSC	**Complete.**
GSDO	SCCS 3.0/3.2 valid. Complete (Haz Ops C&C S/W)	**Complete.**
Orion	EM-1 JM Build Start	**Complete.**
Orion	CM Structure Delivery to O&C	**Complete.**
March 2016		
Orion	ITL-02: Dual String C&DH Integration Complete	**Complete.**
SLS	S/W Rel. 12 (Green Run)	**Complete.**
SLS	SPIE CDR Board Part 2	**Complete.**
SLS	Start SITF-Q Testing	**Complete.**
April 2016		
SLS	EM-1 Motor First Segment Cast (Aft)	**Complete.**
Orion	CM Pressure Proof Test	**Complete.**
Orion	ESM CDR Kickoff	**Complete.**
Orion	ESM FM-1 Structural Assembly Complete	**Complete.**
Orion	Start EM-1 CMA Assembly (Inner Walls)	**Complete.**

May 2016		
SLS	LVSA STA Production/Final Assembly Complete	**Complete.** Completed in June, now in instrumentation.
SLS	Core Stage STA VAC Welds Complete	**Under Review**. Completion of STA weld ops expected in Aug 2016**.**
June 2016		
ESD	Build to Sync Kickoff	**Complete.**
Orion	ESM CDR Board	**Complete.**
SLS	QM-2 Static Test	**Complete.** Test occurred 6/28/16.
GSDO	SSCS 3.3/3.4 Validation Complete	**Complete.**
Orion	CMA Composite Aft Wall Delivery	**Under Review.** Composite material debond/cracking issue resolution in work. ECD is August.
Orion	CMA Inner Wall Delivery	**Complete.**
Orion	Orion Emulator delivery to SLS	**Under Review.** SLS FSW 11 content issues (input to Orion emulator) requires redelivery. ECD is August.

ESD EM-1 INTEGRATED MISSION MILESTONE SUMMARY

NASA ESD
Chart Updated: 6 July 2016, Rev A



For comments contact mark.e.ogles@nasa.gov

Exploration Systems Development Top Concerns

Concern	Current Status
Integrated avionics and software verification and validation (V&V): Integrated Test Lab capacity, software delivery status, agile software development process productively metrics and cross-program interdependencies for emulators and design functionality.	Integrated Avionics Software-Integrated Technical Team (IAS ITT) agile software metrics in place. Cross-program dependencies are mapped and content migration is monitored.
Verification and validation (V&V): Plan involves distributed multi-site activities such as structural dynamics testing, environmental test, and functional check out leading to design and integrated flight certification traceable to requirements closure and certification of flight readiness (COFR) with sufficient resources and testing.	V&V plans have been reviewed and are baselined, Enterprise V&V Team (EVVT) Focus Planning In Work, T&V resources are a watch item. Build to Sync (BTS) kickoff complete. Continuing to work with engineering and others on V&V and IV&V opportunities.
Budget: Out-year funding uncertainty impacts to program/cross-program technical integration, interfaces, EM-2 (EUS) mission definition and content, interdependencies management, ground infrastructure, and efficiency of program planning and implementation.	FY 2016 appropriations provide near-term stability. Out-year funding uncertainty remains a watch item.
GSDO: Mobile Launcher (ML) outfitting and V&V including ground system control software/Ground Flight Application Software (GFAS) and Spaceport Command and Control System (SCCS) necessary to support offline processing at MPPF and integrated processing in VAB. Dependencies on cross-program flight/ground hardware interfaces and software. Ground processing first flight learning curve.	GFAS and SCCS are watch items. ML government furnished equipment delivery concerns and firm-fixed price contract performance are watch items.
Orion: ESM CDR completion and FM-1 delivery to KSC. Crew Module (CM)/ESM structural analysis and environmental T&V planning and resource availability for parallel work at KSC Operations and Checkout (O&C) and GRC, preparations for CM and CM Adaptor (CMA) outfitting at O&C (parts availability).	ESA CDR completed with significant forward work identified. ESM primary structure currently in Bremen for outfitting; scheduled for clean room operations in July. Testing at Plum Brook continues to go well. CMA outfitting at O&C in work and ESM delivery are watch items.
SLS: Vertical Assembly Center (VAC) welding operations, TPS spray operations and core stage integrated assembly at MAF through green run test. RS-25 controller status. Outfitting of core stage engine section this fall.	VAC operations continue to be a watch item. Core stage contract re-plan complete. EUS baselined for EM-2 with Preliminary Design Review (PDR) in December. RS-25 controller delivery a watch item.
Long-Term Sustainability: Productions and operations (P&O) sustainability at the rate of one flight per year after EM-3 by reducing cost. Mission planning for EM-2 and beyond including on ramp for low-cost opportunities for development tech objectives and capability enhancements.	P&O study conducted as part of FY18 budget formulation to further identify cost reduction opportunities, numerous program efforts also in work. Dedicated Mission Analysis and Integrated Assessments (MAIA) team established and focused on EM-2 mission trades.
EM-2: Test flight, first crewed flight risk and related mission planning, including co-manifested payload and docking systems capability determination.	Vehicle systems check out timeline and EUS boil-off trade, trajectory options, and EM-2 test flight objectives being evaluated by MAIA.

ESD Audit Summary, 2015 - 2016

NOTE: Includes only IG/GAO audits where ESD programs were a major focus. Does not include the full breadth of independent program evaluations (SRB, IRTs, LCR briefs, ASAP, NAC, Agency financial and performance reviews, etc.)

CY 2015

- GAO-15-596, SLS Cost and Schedule
- IG A-15-014-00: Plum Brook Station
- IG A-14-019-00: Agency JCL Process
- IG A-13-020-00: Infr. Modern., GSDO
- IG A-13-020-00: Infr. Modern., Comm.
- GAO Quicklook Book (SLS)
- GAO Quicklook Book (Orion)
- GAO Quicklook Book (GSDO)
- GAO-16-620: Orion — 60-day
- GAO-16-612: SLS and GSDO — 60-day
- IG A-15-003-00: Orion — 60-day

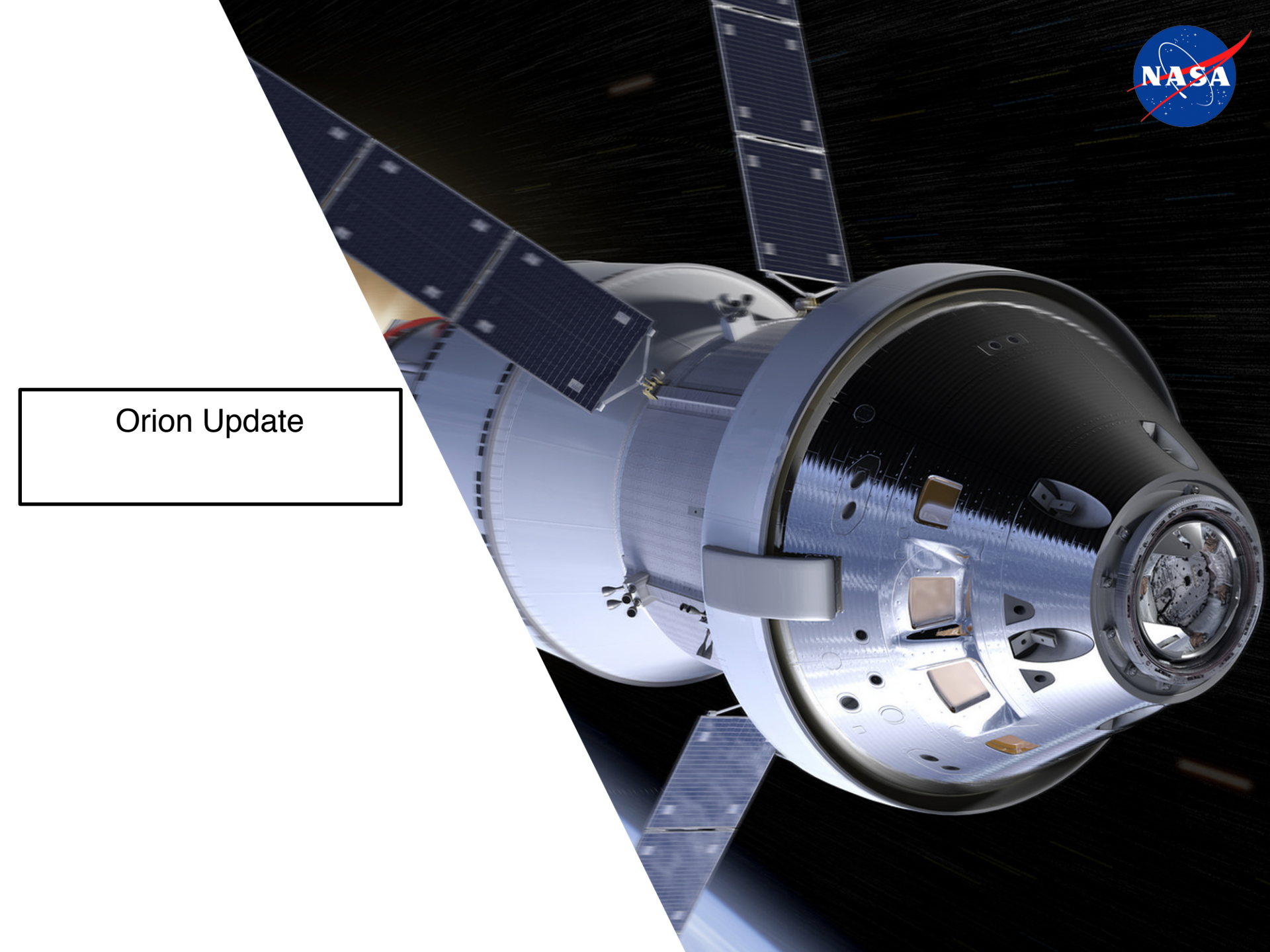
CY 2016

Major Upcoming Program/Enterprise Activities Through Rest of CY 2016:

- **Enterprise Build to Synchronization**
- **Orion CDR2 outbriefs**
- **SLS core stage IBR**
- **SLS EUS and USA RFPs**
- **SLS element DCRs**

- GAO Quicklook Book (SLS), with new metrics
- GAO Quicklook Book (Orion), with new metrics
- GAO Quicklook Book (GSDO), with new metrics
- IG A-16-015-00: Exploration
- IG A-10-016-00: 4693/4697
- GAO 100996: SLS, Orion, EGS
- GAO 101003: ESD Integration

Orion Update



Orion Recent Performance

Program

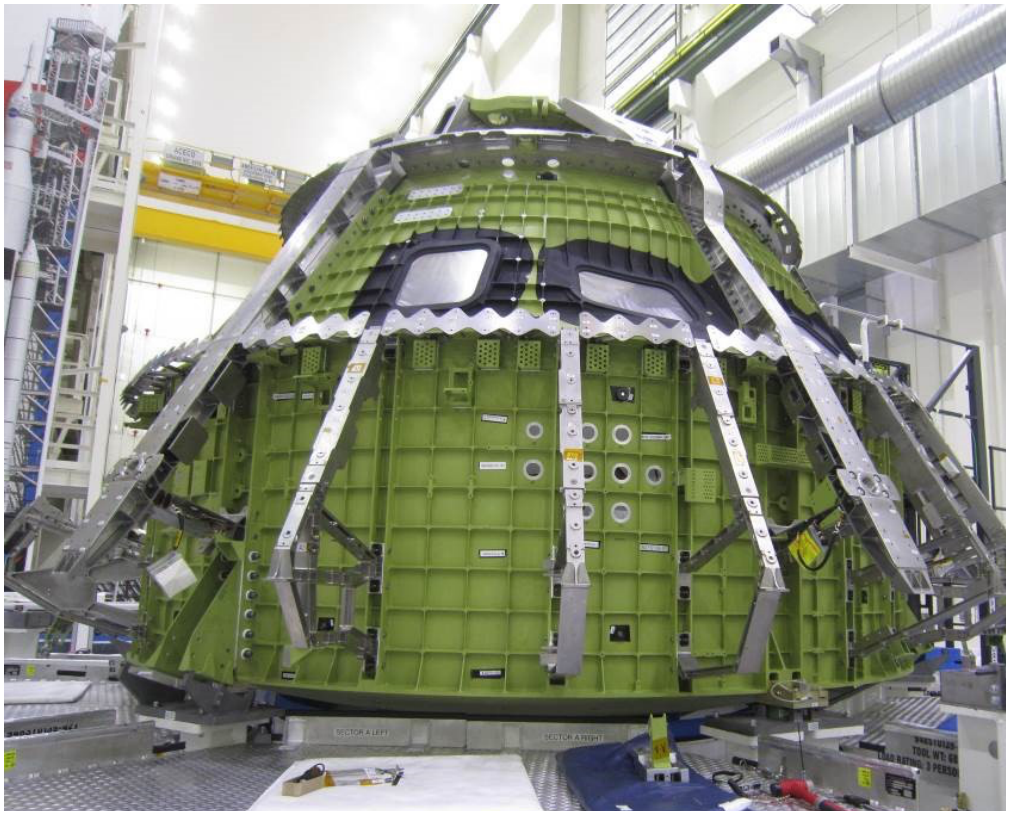
- ✓ Post CDR Program Sync May 2016
- ✓ ESM CDR Board June 16, 2016
- – CDR Phase II DPMC Aug 2016

Launch Abort System (LAS)

- ✓ EM-1 Jettison Motor build started February 2016
- – Attitude Control Motor (ACM) hot fire test (HT-11) October 2016
- – Abort Motor and ACM Assembly Complete October 2016

Crew Module (CM)

- ✓ Shipped pressure vessel to KSC to begin spacecraft assembly February 2016
- ✓ Proof pressure test in April 2016
- – Clean room operations complete and propellant line proof and leak test September 2016
- – Initial power-on by January 2017



The Orion EM-1 Crew Module being assembled at the Armstrong O&C Building at Kennedy Space Center in Florida

Orion Recent Performance (cont.)

Service Module

- Service module is comprised of two elements; a European Service Module (ESM) and a Crew Module Adaptor (CMA)

- ESM Structural Test Article (eSTA) version of the ESM built by Thales Alenia Space Italia
  - ✓ Delivered to Plum Brook Station and integrated with Crew Module Adaptor (CMA) in November 2015
  - ✓ Acoustic testing successfully completed in May 2016
  - ✓ Vibration testing began in June 2016

- ESM EM-1 flight structure
  - ✓ Built by Thales Alenia Space Italia and delivered to Airbus in Bremen, Germany in April 2016
  - – Enters Bremen cleanroom in July 2016

- EM-1 Crew Module Adaptor (CMA)
  - ✓ Assembly start in April 2016
  - – Enters cleanroom in August 2016
  - – Propellant and ECLSS proof pressure test in Sept-Oct 2016
  - – Initial power-on in January 2017

- ESM and CMA EM-1 flight articles ready for mating into the EM-1 SM Spring 2017

The Structural Test Article of the European Service Module begins vibration testing at Plum Brook Station, OH.

SLS Update

SLS Recent Performance

Program

- ✓ SLS CDR briefings complete – Oct 2015
- – SLS Design Certification Review (DCR) – Jan 2018

Interim Cryogenic Propulsion Stage (ICPS) & Adapters

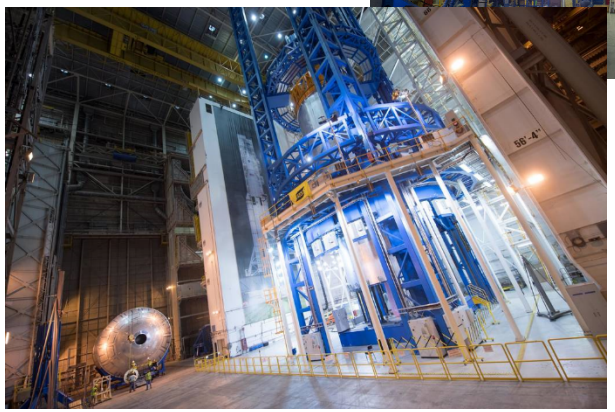
- ✓ Completed SPIE CDR 2 Board – Mar
- ✓ Completed LVSA Fwd to Aft Cone Weld – Mar
- ✓ Completed LOX Tank Proof Testing – Apr
- ✓ Completed vertical welds and NDE of EM-1 Orion Stage Adaptor (OSA) – May
- ✓ Deliver ICPS Structural Test Article (STA) to MSFC – Jun
- − Start Integrated Structural Test – Dec
- − EM-1 ICPS Production Complete - Feb
- − Complete Integrated Structural Test – Feb

Stages

- ✓ LH2 Tank WCA VAC Welds Complete – Jan
- ✓ Started LOX Tank WCA VAC Welds – Feb
- ✓ Completed Engine Section Structural Qualification Article Weld on VAC – Mar
- ✓ Completed Engine Section Flight Unit Weld on VAC – Apr
- ✓ Contract mod signed – May
- ✓ CS-1 Forward Skirt Vertical Welds Complete – Jun
- – LH2 Qual Tank Pneumatic Proof Test – Jul
- – Integrated Baseline Review - Jul
- – Completion of all qual and EM-1 flight article VAC welding operations – Aug

ICPS Structural Test Article arriving at MSFC

LVSA Structural Test Article



LH2 Tank Qualification Article In VAC welding

SLS Recent Performance (cont.)

Booster

- ✓ EM-1 Left & Right Hand Booster Production progressing
  - ✓ Both left & right center/center segments have completed insulation
  - ✓ EM-1A (left) aft and center-forward completed casting
  - ✓ EM-1B (right) center forward segment has completed casting
- ✓ Started EM-1 Aft Skirt refurbishment – Feb
- ✓ Completed cast and cure of first flight segment (left aft) – Apr
- ✓ QM-2 Test Firing – June 28
- – EM-1A forward segment cast – Jul
- – EM-1B aft segment cast - Aug
- – Booster Battery Qual Testing Begins – Aug

Successful QM-2 Test

EM-1 Left Aft segment lowering into casting pit.

Engines

- ✓ Flight Engine Control Unit (ECU) Production began – Jan
- ✓ Completed ECU Software Build 3 Hardware-in-the-Loop verification & validation – Feb
- ✓ Completed Engine 2059 RS-25 Test – Mar
- ✓ Held RS-25 Production Re-start IBR – May
- ✓ Install RS-25 E0528 in A1 test stand – Jun
- – Start next round of RS-25 Engine Tests (E0528) – Jul
- – Flight Controller 1 (FM1) Final Assembly ATP – Jul
- – FM1 Qual Testing begins – Sep
- – RL-10 Contract with AR for Full Production – Oct

Engine Controller EM-5 installed on E5028

SLS Recent Performance (cont.)

Avionics / Software

✓Stages Redundant Inertial Navigation Unit (RINU) Development Test data delivered to support validation & verification – Jan

✓Began Release 13 Sprint 3 – Mar

✓Completed Phase 1 SITF-Q Testing – May

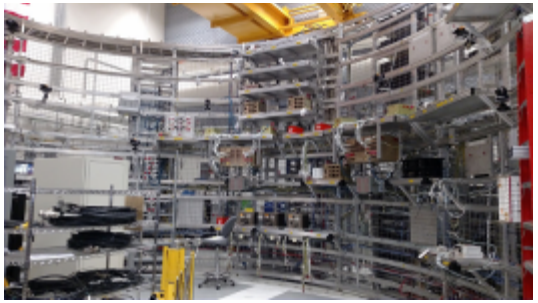
–Begin Phase 2 SITF-Q Testing – Jul

–Deliver Flight Software Release 13 – Nov

–Deliver Flight Software Release 14 – Jun 2017

Facilities

- ✓ Official Start of SSC B2 Activation – Jan 2016
- ✓ Test Stand 4697 (LOX Tank) Topping Out event – Mar
- ✓ Test Stand 4693 (LH2 Tank) Topping Out event – Apr
- – Engine Section Structural Test Facility Ready – Nov
- – CoF Complete for LH2 Test Stand (4693) – Dec



SITF-Q Facility Testing

Test Stand B-2 at Stennis Space Center

Test Stand 4693 (LH2) at Marshall Space Flight Center

GSDO Update

GSDO Recent Performance

Vehicle Assembly Building

✓ Five of ten platforms (K, J, H, G, and F) are installed in High Bay 3 (HB3) with platform testing continuing

–Platform halves E and D are in process of detail outfitting in HB-4 and the Transfer Aisle. Platform installations behind plan due to initial issues with Platform K installation.

LETF Umbilical Testing

–The LETF is working 2 shifts and is actively testing ML umbilicals

– Aft Skirt Purge Umbilical [ASPU] – testing started and working through technical issues
– Orion Service Module Umbilical [OSMU] – resolving issues with the LAS QD pull-off and expect testing to complete in July
– Vehicle Support Posts [VSP's]) – 4 of 8 VSPs have been delivered to the LETF
– Core Stage Forward Skirt Umbilical (CSFSU) – Remaining fabrication work was pulled in-house to prevent further schedule delays. Umbilical has been hung on the test tower and set-up is well underway. TRR is scheduled for mid-July.
– ICPSU – test set-up is in-work – vehicle motion simulator will be re-configured after OSMU, so testing is contingent on OSMU completion
– Core Stage Inter-Tank Umbilical (CSITU) - Remaining fabrication work was pulled in-house to prevent further schedule delays

VAB Platform G-South Install

ICPSU Testing Preps

GSDO Recent Performance (cont.)

Crawler Transporter Status

- ✓ The Crawler Transporter Element Integration Team completed the steering arm refurbishment. All new Jacking Equalizing and Leveling (JEL) cylinder upgraded replacements have been installed.
- ✓ The first phase of CT-2 Standalone V&V testing is successfully complete
- – Electrical mods for mini portable purge units (MPPUs) are in-work
- – Future plans include completion of all CT-2 V&V during ML move to the VAB and Pad for multi-element verification and validation (MEVV)

Steering Arm Refurbishment

Pad B Development Status

- ✓ New liquid hydrogen (LH2) separator system and the catacomb roof reinforcement projects have been awarded and Notice-to-Proceed has been granted
- ✓ The architecture and engineering contract for the 1.4Mgal Liquid Hydrogen (LH2) Sphere Upgrade Concept Validation and siting selection has been awarded and kicked-off
  - ✓ The effort will include a recommendation for final site selection and provide detailed subsystem requirements for a year long design effort starting at the beginning of FY 17
  - – The Concept Validation effort will culminate in a System Requirements Review
  - – The new additional LH2 sphere is required to support SLS Block 1B launches using the Exploration Upper Stage (EUS)

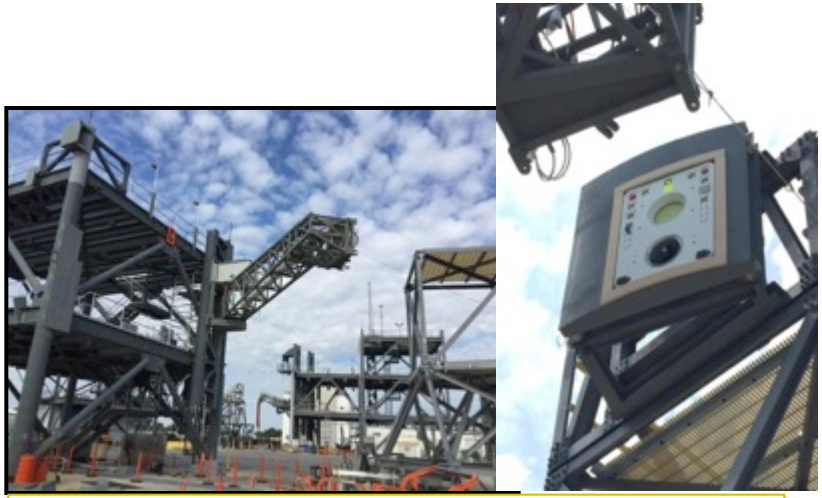
Launch Complex 39-B

GSDO Recent Performance (cont.)

Mobile Launcher Status

- ✓ On-going negotiations with GSE Install contractor will include multi-shift/weekend work
- ✓ In-process of implementing a 2nd shift in the LETF to ensure timely delivery of umbilicals to ML
- ✓ The remaining design work has been divided into work packages that are envisioned to enable more timely implementation and aimed at mitigating schedule concerns
  - ✓ Completed and delivered work packages 1 & 3 to GSE installation contractor
- – Discussing additional options with GSE install contractor to further accelerate completion date by up to 5 months
- – Working closely with KSC procurement to facilitate dispositioning future change orders
- – Beam, Frame, and Bracket Fabrication at shop (Continuous)
  - – Misc. Tower bracket installation (Continuous)
  - – Working to complete Shear Clip Installations

TSMU Housings Delivered to be Outfitted



CSFSU hung on the LETF Tower C for testing

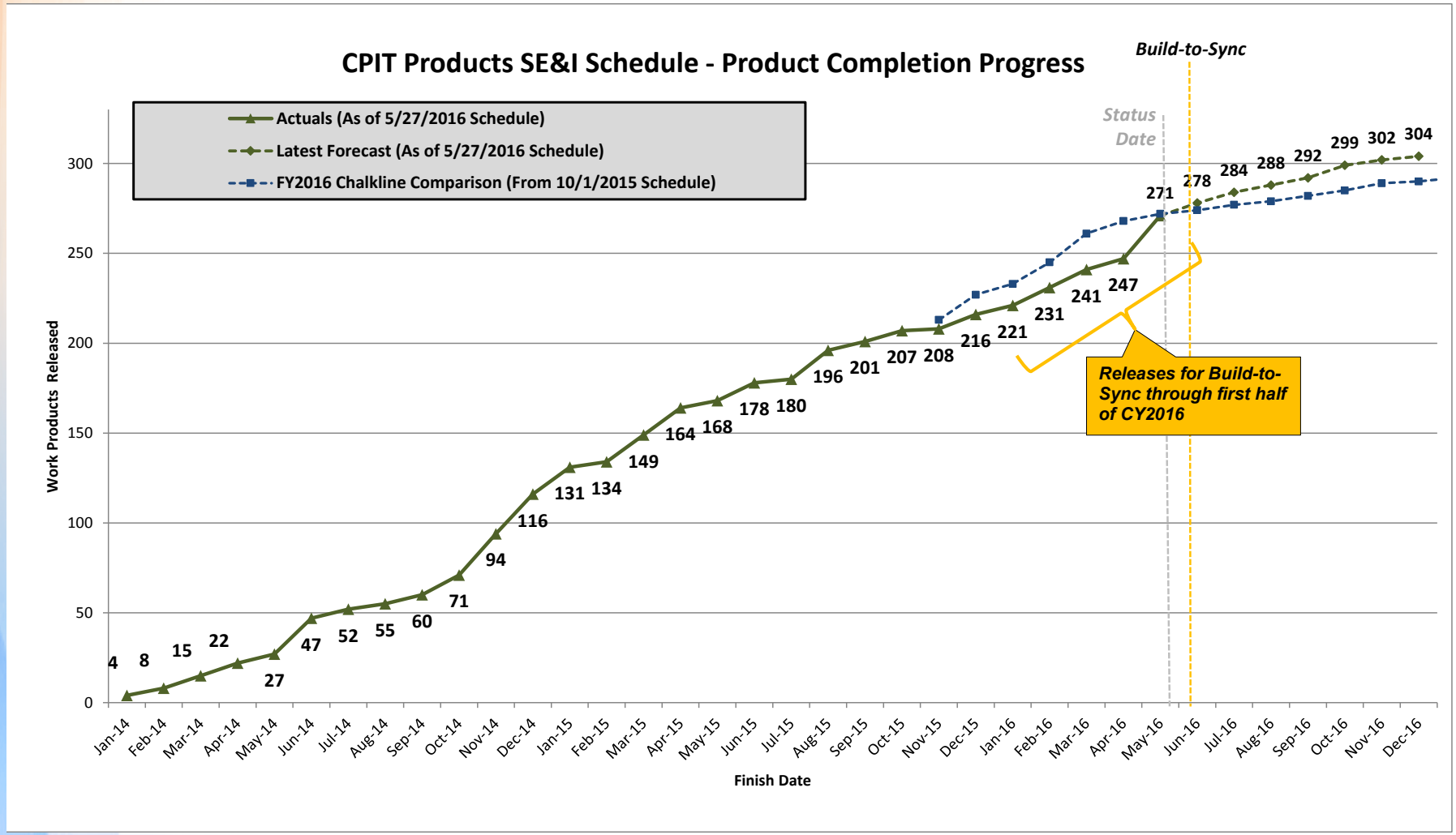
Cross-Program Systems Integration Update

CSI Technical Performance and Accomplishments

- Recent Major Cross-Program Accomplishments (June – July)
  - Update Orbital Debris Assessment Report (ODAR) for BTS (June)
  - Complete Orion ESM CDR (June)
  - Cross Program Physical Configuration Audit (PCA) Plan (June)
  - Orion-GSDO Simulation to Simulation ICD (June)
  - Cross-Program Design Model Log to Rev F (June)
  - Baseline Cross-Program Wet Dress Rehearsal (WDR) Test Plan (June)
  - Cross-Program Fault Management (FM) Capabilities (July)
    - Volume 1: SLS Vehicle Abort Triggers Definition (ATD), to Rev C
    - Volume 2: SLS Vehicle Caution and Warning (C&W) Conditions, to Rev B
    - Volume 3: SLS Vehicle Safing Conditions and Actions, to Rev C
  - ESD Day of Launch I-Load Update, Vol. 1: DOLILU Concept of Operations to Rev A (July)
  - ESD Human Systems Integration Plan (HSIP) to Rev A (July)
  - Cross-Program Integrated Vehicle Ascent Timeline, to Rev A

- Near-term forward work
  - Baseline Cross Program Integrated Communications and Network (ICAN) Test Plan (July)
  - Baseline ESD Mission Integration Implementation Plan (MIIP) (July)
  - EM-1 Mission Definition Baseline (July)
  - Baseline Cross-Program Processes and Agreements for Launch Site Ground Operations (July)
  - ESD (L1) Requirements to Rev E (July)
  - Update ESD Con Ops for the Exploration Upper Stage (July/August)

CPIT SE&I Schedule
Product/Revision Completion Progress



Cross Program Interdependencies - Management and Status

CSI team continues to manage Interdependencies, working with ESD and Program schedulers to ensure Program needs are being met

- Major deliveries last quarter include:
  - SLS and Orion Software updates
  - LETF testing hardware and early facility installation hardware
  - Data needs to continue Verification activities
  - Model exchanges including detailed CAD models, FEMs, dynamic models associated with Verification Analysis
- Significant upcoming deliveries include:
  - SLS and Orion Software updates
  - Hardware and Data needs to continue Verification and Testing activities
- The team is watching several items discussed as Top or Emerging issues will have interdependency impacts or be negotiated through the interdependency process

Since 2012, 817 (formerly 710) interdependencies have been identified by the team, with 267 (formerly 218) currently active

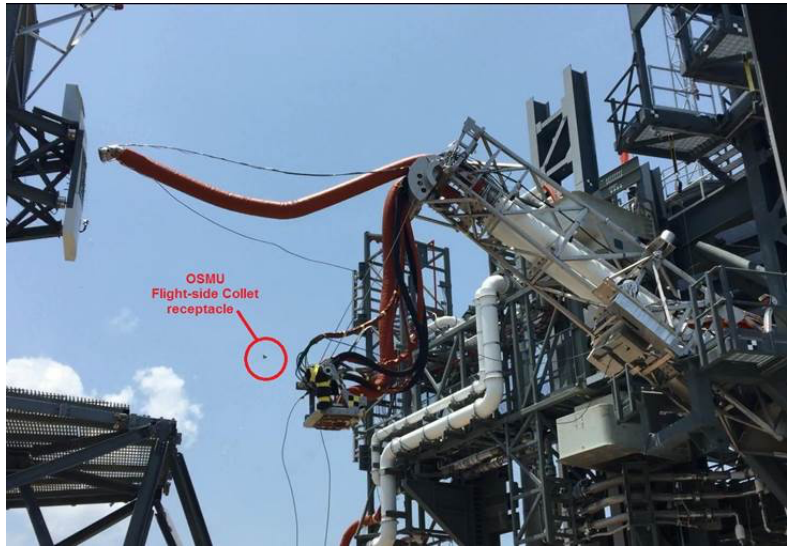
Interdependencies Category Definitions
Candidate – An item that has been identified as an interdependency by one program, but formal agreement with the providing program has not been achieved.
Partnered (In Work) – An item has been agreed by the providing program to provide scope on the requested need date, but has yet to be received by the requesting program.
Baselined - An item has been approved in the baselined BSHEALS or BDEALS documents
Under Review (Delivered) – An item/delivery that has been received and is presently under review prior to formal acceptance.
Elevated – An item that has been elevated to the CPIT Leadership, as no resolution has been reached at the ITT/working group level, or need date has passed.
Closed – An item has been received, reviewed, and formalized.

CPIT Top Technical Issues

- ESM propulsion zero fault tolerant bellows design
  - GSDO set up a team to assess impact and any potential hazard mitigations (continuous leak monitoring and contingency depress and de-service at all KSC facilities), Feb 2016
  - Orion proceeding with 0 Fault Tolerance bellows for EM-1; will fix bellows for EM-2; implement parallel prop design by EM-4; Reviewed by ECB for approval in March 2016
  - GSDO impacts were approved at the JPCB on 6/2/16
  - **Issue Closed**

CPIT Top Technical Issues

- Production umbilical plate collet delivery
  - Redesign in mid-2015 was performed to minimize the amount of movement of the plungers and prevent premature release of the mechanism.
  - Collet would not release in subsequent development testing
  - Further design changes – increasing spring size, addition of lubrication, and removal of sharp edge – made with successful test results
  - Had successful testing of primary release mechanism at LETF
  - During secondary release testing at LETF, collet receptacle came free instead of remaining attached to collet. Investigation in work.
  - **Issue Reopened**



CPIT Top Technical Issues

- TBX burndown in Orion-GSDO ICDs, Volume 1 (Hardware)
  - MPCV-IRN0006-X approved at JPCB on 6/23/16 closed 9 of the remaining 16 TBXs.
  - MPCV-IRN000n-X in Sept 2016 will close 7 remaining TBXs
- GSDO Ground to Flight Applications Software (GFAST)
  - GFAST development is highly dependent on agreements for products (CUI, OMRS, LCC, XTCE) to be delivered on time by other programs.
  - Have made early draft OMRS and LCC content from Orion and SLS available to support GFAST development
  - Multiple coordination meetings have occurred; agreements team working to partner all required dependencies

CPIT Top Technical Issues

- OSMU Involvement with URRT
  - Performing the mechanical release and retract with the OSMU could damage the ground and/or flight plate and cause a significant risk to continued processing and launch
  - Trade study team developed plan to use test plate on the ground side with removal of electrical and fluid connectors to minimize potential for damage to flight hardware.
  - Plan will be reviewed at 7/12 JICB and 7/15 JICB.

CPIT Top Technical Issues

- ICPS Umbilical Loads (new)
  - Latest integrated loads showed that ICPS loads were >200% over hardware design loads.
  - Team continues to work toward resolution. Models are being reviewed for accuracy with Boeing at KSC working with GSDO analysts.
  - Evaluating hose cradle with bungee cords to reduce moment loads

- VSS Timing (new)
  - Currently VSS clearance is showing positive, however, the interface does not actually separate until around a max of T+ 220 Msec. This could have an impact on liftoff loads.
  - JICB action to look at possible early separation of the VSS. Looking at sending the VSS release command from the ground at T-.250 (TBR) in order to insure separation and no load by T-0.
  - Action was briefed to the JICB 5/25/16. JICB directed additional assessments to be performed to allow for a fall 2016 decision

Emerging Cross Program Issues/Concerns

- Day of Launch I-Load Update (DOLILU) Con Ops
  - Discussing processes to be used for wind splicing and load indicators
- Integrated loads
  - Discussing any augmentation required to program testing and analysis plans with the NESC
- Modal test instrumentation
  - Discussing additional accelerometers inside the Orion CM for integrated stack modal testing

ESD CE Issues and Concerns

- Integrated Avionics and Software
  - Software development; ability to maintain schedule and content required across Enterprise
  - ITL throughput and capacity
- Verification and Validation
  - Integrated Avionics and Software “distributed” V&V plan and resources
  - Completion and adequacy of integrated test plans
  - Interface maturity and interface V&V
  - Cost and schedule pressures impacting V&V testing plans for EM-1
- European Service Module
  - Delivery delays could cause impact to ITL and to integrated test and checkout
  - ESM limitations affecting mission capability (power, thermal, serial prop design impacting mission planning for EM-2 +)
- EM-2 Status
  - Settling on final vehicle configuration (Docking, co-manifested cargo, etc.)
  - Mission Profile
  - SE&I workforce for EUS integration concurrent with Block 1 verification

Major ESD/CSI Independent Assessments In Progress

- End-to-End trajectory optimization
  - Ongoing and performing trade studies in launch period and launch window
- Independent modeling and simulation of separation events
  - Liftoff clearance, booster sep, Orion panel sep, Core Stage/ICPS sep, starting EUS
- Modeling for Rollout Loads
  - Crawler/Transporter (CT), Mobile Launcher (ML), and Forcing Functions; task complete
- Peer Review of Enterprise Modal Testing
  - Also includes Development Flight Instrumentation, ESD impacts in work
- Evaluation of ORDEM 3.0 MMOD environment
  - In work, using data from available on-orbit assets
- Enterprise Verification and Validation Assessment
  - In work, expect to complete in June
- Review of the Orion-ESM Interfaces
  - Completed in April
- Independent Verification of Ascent Abort Loads
  - Tool development complete, analysis pending

Questions?

Backup

Orion Accomplishments

Five of nine water drop tests at Langley Research Center in Virginia

European Service Module Structural Test Article (ESM STA) completes acoustic testing Glenn Research Center Plum Brook Station in Ohio

ESM STA solar panel array deployment test at Glenn Research Center Plum Brook Station in Ohio

Orion avionics mockup at the Lockheed Martin Integrated Test Lab in Littleton, Colorado

EFT1 Crew Module acoustic testing at Lockheed Martin in Littleton, Colorado

Suited hand controller evaluation in the medium fidelity mockup at the Johnson Space Center in Houston, Texas

SLS Accomplishments

Launch Vehicle Stage Adapter STA Complete

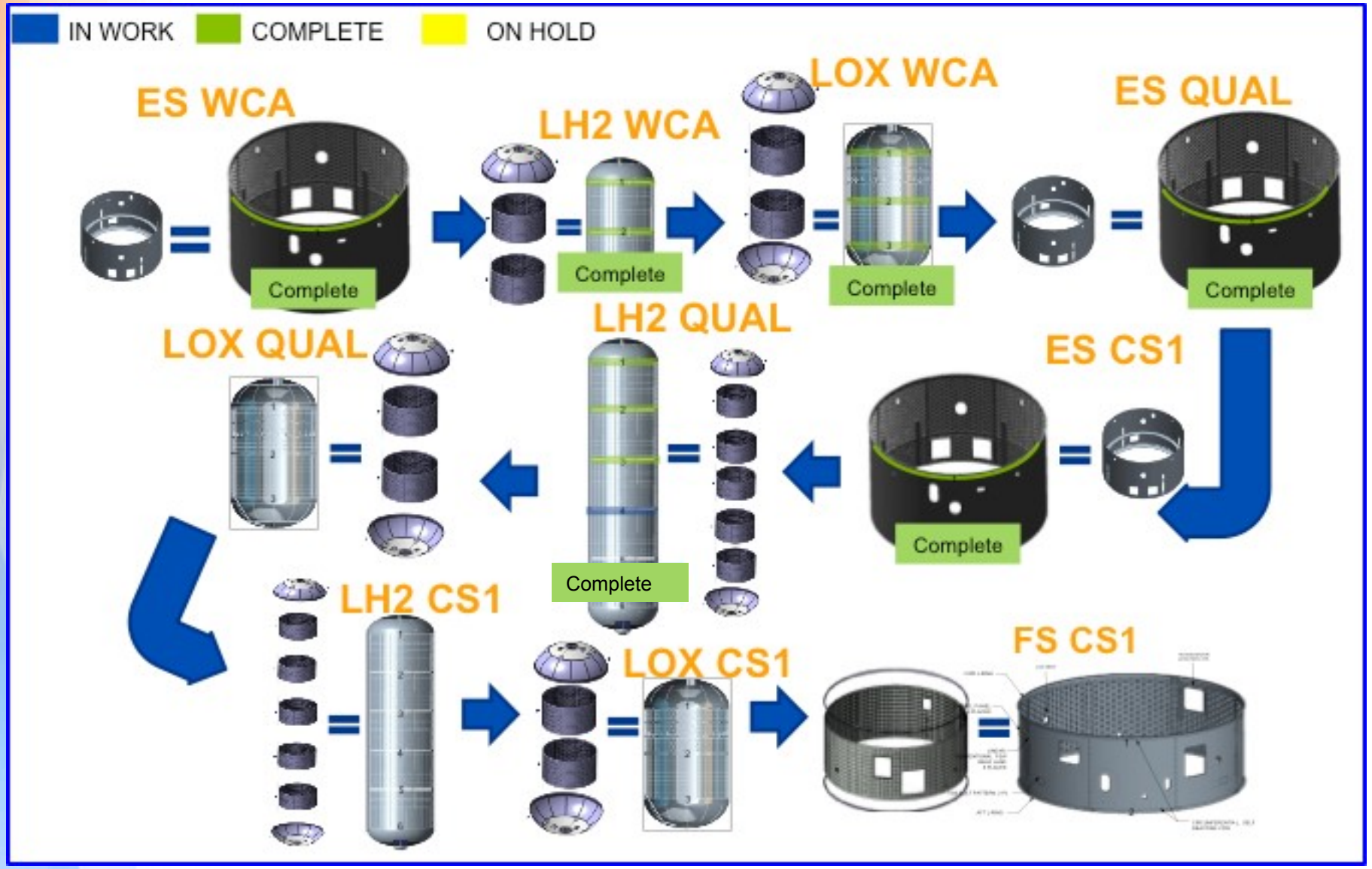
Engine 2059 removed from stand

Interim Cryogenic Propulsion Stage STA delivered to Marshall

Qualification Motor-2 Booster chill-down for June 28, 2016 test

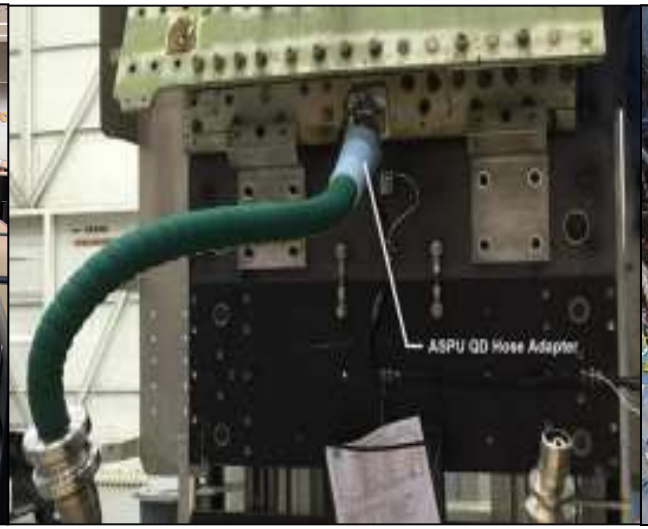
Liquid Oxygen Tank STA completed vertical welds

VAC Flow Status



Ground Systems Development & Operations Accomplishments

Completion of SCCS 3.4 Software Verification

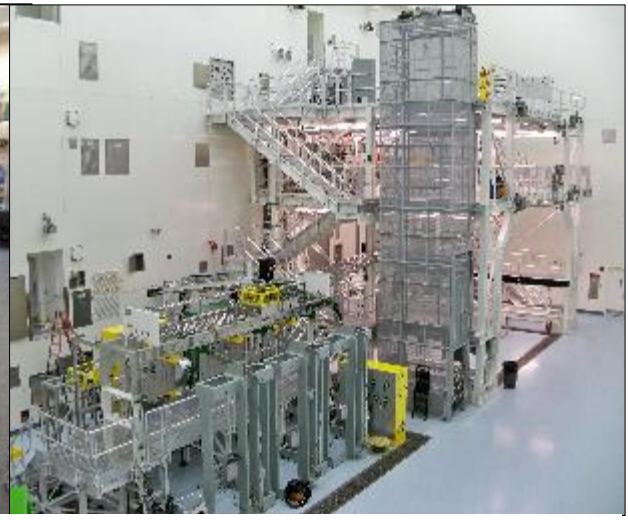


Aft Skirt Purge Umbilical Purge at LETF

Platform G installed in VAB

Refurbishment of Flame Trench at Pad B

Program puts students 'FIRST'



Multi-Payload Processing Facility ready for V&V phase